Geoarchaeological investigations at Akko, Israel: New insights into landscape changes and related anchorage locations since the Bronze Age

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ABSTRACT

Since the first archaeological excavations undertaken in the 1970's/1980's, Tel Akko is known to have been an important trade city from the early 2nd millennium BC onwards. Even if the site has been intensively excavated, no palaeoenvironmental studies looking to understand coastal changes near the tell since the Bronze Age had been undertaken until recently. Our research is based on the study of sedimentological cores drilled at the foot of the tell and in the Old City of Akko, 1500 m west of the tell. We validate the coastal changes, already proposed by previous studies, while clarifying the chronology of these changes. We propose that he southern anchorage was located in the river-dominated mouth of the Na'aman until the early Persian Period. This anchorage shifted to the "open" western coast of the tell during the Persian Period before its subsequent relocation to the rocky promontory of Akko in Hellenistic times. We attempted to locate the Hellenistic harbour of Akko by coring in the Old City, in proximity to the modern harbour. At that time, one harbour was in a semi-protected pocket beach at the foot of the promontory.

Keywords: *Tel Akko, ancient harbour, coastal changes, geoarchaeology, geomorphology, Haifa Bay, Israel, Na'aman River, paleogeography.*

INTRODUCTION

From the earliest antiquity, coastal populations, in search of sheltered anchorage areas, have favoured river-mouth environments. In the context of the southern Levantine coast, this hypothesis was first advanced by Raban (1985) to explain the significant number of coastal sites established near estuaries during the Bronze Age. Although such environments certainly constituted sheltered areas during storms and high swell, they were subjected to natural hazards of both continental and marine origin, mainly linked to high sediment supply leading to coastal progradation (Anthony, 2009; Anthony, Marriner & Morhange, 2014; Morhange et al., 2015). In the microtidal regime of the Levant, we can identify wave-dominated lagoonal estuaries partially open to the sea by an inlet (Reinson, 1992). These estuaries are morphologically different and smaller than the common incised valley estuaries (Boyd, Dalrymple & Zaintlin, 2006). Nowadays, the former estuaries of the southern Levant are mostly infilled and are no longer navigable. By contrast, the coastline of Prehistoric Gaza was more indented and the estuaries must have served as natural semi-protected harbours, as was the case for the navigable estuaries of Wadi Ghazzeh (Morhange *et al*., 2005). These estuaries were progressively infilled due to the regularisation of the coastline, driven by high sediment supply and longshore drift (Figure 1; Stanley, 2002; Morhange *et al*., 2005). In ancient times, the best natural anchorages of the region were located in Haifa Bay (Raban, 1991; Zviely *et al*., 2006). Facing Tel Akko, Tel Abu Hawam was the other major coastal city of the bay during the Bronze Age. It was situated at the mouth of the Kishon River, presently situated 1.5 km inland. This “port of trade” has furnished strong evidence for the environmental problems linked to the infilling of river outlets (Artzy, 2006; Balensi, 1985 and 2000).

Tel Akko was founded around 2000 years BC (Artzy & Beeri, 2010). It was an important city-port between the Bronze Age and the Hellenistic period. We propose that natural processes, in particular sediment inputs, progressively led to a degradation of the harbour facilities, partly explaining the shift of the port-city to the Akko promontory.

Using new sedimentary cores our aims were:

(1) to test and nuance the landscape evolution of Tel Akko suggested by Morhange *et al*. (2016) and to investigate the different anchorage areas from the Bronze Age to the Late Persian Period.

(2) to investigate a depressed zone in proximity to the present harbour of the Old City, close to Khan el-Oumdan, in order to locate the Hellenistic harbour, that moved westward (as did the whole city) in Hellenistic times (Marriner, 2009; Galili *et al*., 2010; Artzy, 2012; Artzy, 2015).

GEOMORPHOLOGICAL CONTEXT

The ancient site of Tel Akko (Figure 2) is located some 1.5 km east of the Old City of Akko (Saint-Jean-d'Acre) on Tell el-Fukhar (the tell of the sherds). The tell is situated in the northern part of Haifa bay that constitutes the extension of a continental graben flanked by two normal faults and delimited by the Carmel promontory to the south and the Akko promontory to the north. These faults were principally active during the Miocene and the Pliocene, while neo-tectonic activity appears to be modest during the Late Holocene in the area of Akko (Sivan, Gvirtzman & Sass, 1999). The tell is situated on a fertile agricultural plain, with plentiful water supply from natural springs and rivers (Artzy & Beeri, 2010). It is boarded by a sandy beach open to waves coming from the west. Coastal changes in the Zevulun plain during the Late Holocene are related to sea-level change and sedimentary inputs. The maximum sea incursion in Haifa Bay occurred 4000 years ago, flooding the Zevelun plain under several meters of sea water and leading to the displacement of the shore some 4 km landward (Zviely *et al*., 2006; Figure 2). After the stabilisation of relative sea-level around 3650 years BP (Porat, Sivan & Zviely, 2008), coastal progradation resulted from the combined action of fluvial, aeolian and marine sediment inputs. In fact, (1) the bay drains the water of two coastal rivers, the Kishon River to the south and the Na'aman River to the north that transport sediments to the plain, particularly during floods in a similar manner to present-day flood events (Vachtman *et al*., 2012). Here, we focus on the Na'aman River because the change of its course during the last 4000 years has been one of the main drivers of environmental changes near Tel Akko. Flowing at the foot of the tell during Antiquity, the Na'aman is now artificially banked and located some 800 meters to the south. (2) Haifa Bay constitutes the northernmost and final sediment sink of Nile-derived quartz sand, transported from the Nile Delta by longshore currents. This is the bay's main sedimentary source with an average annual quantity of sand of about 80,000-90,000 m^3 being transported before the 20th century (Zviely, Kit & Klein, 2007). (3) Coastal sediments progressively formed important dune fields covering almost the entire western margin of the coastal plain (Figure 2).

ARCHAEOLOGICAL CONTEXT AND HYPOTHESES REGARDING THE LOCATION OF THE ANCIENT ANCHORAGES

History

The name Akko first appeared, with several other coastal sites, in the Ebla texts, dating to ca. 2400-2250 years BC (Artzy & Beeri, 2010). Later, the ancient settlement is mentioned in the Ras Shamra tablets and Amarna letters (Pharaohs of the 18th and 19th dynasties; 1478-1213 BC.). In the Old Testament, the book of Judges (Judges 1:31)[1] indicates that the city is under the control of the tribe of Asher. Excavations on the tell since the 1970s have exposed a rampart reaching a height of 22 meters and a width of 60 meters dated to the MBIIa (2000-1750 BC; Dothan, 1976; Raban, 1983, 1991). The northern rampart was strengthened and a gate ("Sea Gate") was erected (Dothan & Raban, 1980). Imports from the Lebanese coast as well as from Egypt, Cyprus and Cilicia underscore the importance of the anchorage and the scope of Akko's trade network (Dothan & Goldmann, 1993; Artzy & Beeri, 2010). During the first part of the 1st millennium BC, the site experienced a reduction in population size, probably linked to the transfer of the administrative centre from Akko to Tel Keisan situated 8 kilometres inland (Artzy & Beeri, 2010). The habitation pattern and the population density increased after ca. 700-600 years BC, the period in which Phoenicians, Persians and Greeks were present (Gambash, 2014). The importance of Tel Akko in the trading network of the

[1] Judges: *The Book of Judges*. Webb, B.G., 2012. Wm. B. Eerdmans Publishing, Grand Rapids (Michigan).

Levantine coast during the Persian period is attested by the presence of Greek merchants in Akko mentioned by the orator Isaeus in the 4th century BC (Isaeus, 4, 7)[2]. In 332 BC, Akko fell to Alexander the Great and Ptolemy 2 changed the city's name to Antiocha Ptolemais. The town moved down to the peninsula sometime in the 3rd century BC (Artzy, 2015). The latest numismatic evidence dates the occupation of the tell to the early part of the 2nd century BC (Artzy, 2012). In the Old City of Saint-Jean-d'Acre, remains dating to the Roman period have been found, some alongside later Hellenistic finds (2nd century BC), mainly north of the peninsula (Abu Hamid, 2012) and a large cemetery was installed at the north-western foothill of Tel Akko (Tepper, 2010). From an archaeological perspective, very little is known about the Arab period of Akko harbour. In the early 12th century, the city was conquered by the Crusader army, and became one of the important Crusader ports, where merchants and the military orders settled. In 1187 AD the city was captured by the Muslim army, but in 1191 AD was recaptured during the third crusade, led by Richard the Lion-Heart. Jerusalem remained under Muslim rule and thus Saint-Jean-d'Acre gained importance by becoming the capital and the main harbour of the Kingdom of Jerusalem.

Location of the harbours

Imported ceramics found at Tel Akko demonstrate that the city must have had a harbour since the Bronze Age. Moreover, Haifa Bay provides the best-protected natural anchorages on the southern Levantine coast (Raban, 1985 and 1991; Zviely *et al.*, 2006). Furthermore, these strategic maritime links to the Levant are reinforced by terrestrial routes penetrating eastwards to the Jordan Valley and further to Transjordan. Morhange *et al*. (2016)

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[2] **Isaeus:** *Discours*. Livre 4. Traduit par Roussel, P. Paris, Les Belles Lettres, 1922, 380 p.

proposed that the anchorage of Akko was first situated in a marine-dominated estuary south of the tell during the MBA. Later, the anchorage moved to the open coast on the western side of the tell because of the sedimentary infilling of the Na'aman outlet during the Persian period. Thereafter, the construction of a semi-artificial harbour during the Hellenistic period, in what is today known as the Old City of Saint-Jean-d'Acre, led to the displacement of the city from the tell to the Akko promontory where it remains to this day (Galili *et al*., 2007, 2010, 2017; Artzy, 2012; Gambash, 2014).

METHODS

Biosedimentology

Our work is based on four continuous cores. Three cores were drilled at the foot of the tell and another ca. 1.5 km to the west, in the Old City of Saint-Jean-d'Acre (Figure 3). The coring campaign was undertaken using a percussion corer (Cobra TT). The cores were altitudinally benchmarked relative to present MSL with a GPS-RTK. Core description (texture, macrofauna, organic remains) and sampling were undertaken during fieldwork. Bio-sedimentological analyses were undertaken in the sedimentology laboratory of the CEREGE based on the methodology detailed in Marriner & Morhange (2007) and Marriner (2009). The general sediment texture, including the gravel (>2 mm), sand (50µm - 2mm) and silty-clay (smaller than 50µm) fractions, was determined by sieving. Ostracoda were picked from the >150 µm fraction and identified to species level, when possible, using reference manuals (Athersuch, Horne, & Whittaker, 1989; Lachenal, 2000; Meisch, 2000) and scientific papers (eg. Frenzel & Boomer, 2005; Ruiz et al., 2010; Avnaim-Katav et al., 2016; Salel, Bruneton & Lefèvre, 2016). Macrofossils larger than 1 mm in size were also identified and assigned to assemblages according to the Mediterranean classification system (D'Angelo & Garguilo, 1978; Poppe & Gotto, 1991, 1993; Doneddu & Trainito, 2010).

Chronology

The chronology is based on eleven AMS radiocarbon determinations performed at the Poznan Radiocarbon Dating Centre on charcoal and marine shells (Table 1). We calibrated the dates using Calib 7.1 (Stuiver & Reimer, 1993) and IntCal13 and Marine13 curves (Reimer *et al*., 2013). For dated shells samples, we used a local marine reservoir age of 286 years (Morhange *et al*., 2016; Weighted Mean ΔR = 3; Standard Deviation = 73) calculated using six published ages from Reimer & McCormac (2002) and Boaretto, Mienis & Sivan (2010) (Table 2). The discovery of numerous fragments of ceramics allows us to obtain a high-precision relative chronology for the stratigraphic units thanks to the study of their typology. These results confirm the radiocarbon chronology (Table 3).

RESULTS

Presentation of the cores drilled at the foot of the tell

The two cores presented in the first part (AK-XV-1 and AK-XV-2), were undertaken on the southern side of the tell, they show the same stratigraphy and are divided into three main biofacies. The core AK-XV-3, undertaken on the western facade presents a different stratigraphy and will be presented in another part. Finally, the core AKKO3, drilled in the Old City of Saint-Jean-d'Acre, will be detailed in the third part.

The southern facade of the tell

Core AK-XV-1 (32°55'10.48"N; 35° 5'12.89"E) is located a few tens of metres south of the limit of the tell, 376 cm above the present mean sea level. With a length of 450 cm, it reaches the rocky substratum composed of kurkar (Figure 4).

Unit A: leaky lagoonal estuary at the mouth of the Na'aman until ca. 400 years cal. BC

Unit A, between 300 cm and 450 cm depth, is radiocarbon dated to 2425 ± 30 BP (749 – 404 years cal. BC; Poz-78033) at the base and 2385 ± 30 BP (727 – 395 years cal. BC; Poz-78032) in the middle. The age of this unit is confirmed by the presence of an important quantity of rounded ceramics (4-6th centuries BC) throughout the unit (Table 3). These ceramics derive from amphorae and other pieces that are for the most part imported from Egypt and Greece amongst others. The sedimentary texture of the unit is sandy (>90%), including rounded pebbles probably of fluvial origin. This marine sand is mostly fine, with a few coarse layers at the base of the unit. The ostracod fauna is composed of a mixture of species presenting various ecological affinities. The coastal assemblage is dominant (41%). Sixteen species have been identified. Three of them are dominant, namely *Aurila convexa*, *Loxoconcha rubrincta* and *Pontocythere elongata*. They are characteristic of fine infratidal sands. In the lagoonal assemblage (31%), the species *Cyprideis torosa* and *Xestoleberis communis* prevail. The fresh (to mesohaline) species (26%) are represented by *Candona neglecta*, *Darwinula stevensoni*, *Heterocypris salina* and *Illyocypris gibba*. The latter tolerate low to moderate salinity and are associated with estuaries or low salinity coastal lagoons. They are better adapted to variations in salinity. However, it is important to stress that the ostracod density is relatively low, between 1 and 100 valves for 20 grams of sand. Macrofauna, with a low density in the whole unit, attest to both freshwater and marine influences.

Unit B: choked lagoonal estuary between ca. 300 years cal. BC and ca. 1000 years cal. AD

Unit B, located between 230 and 300 cm depth is dated to 2250 ± 30 BP (394-207 years cal. BC; Poz-78031) at the base. The sediments are composed of organic-rich silts and clay. Even if the sand fraction is less important than in unit A, the latter are coarser, in particular at the base of the unit. The ostracods are associated with fresh to mesohaline water environments. We found the same species as in the previous unit. At the base of unit B, *Heterocypris salina* is dominant then becomes less abundant. It is replaced by *Candona neglecta*, *Darwinula stevensoni* and *Illyocypris gibba*, that point to a decrease in the salinity linked to the closure of the lagoon and the growing influence of freshwater inputs linked to the Na'aman River. In this unit, the ostracods are abundant with 100 to 800 valves for 20 grams of sediments. Coastal ostracods are quasi-absent from this unit. It is important to note that nowadays, *Illyocypris*, *Heterocypris* and *Cyprideis* are still found in the Na'aman river mouth (Avnaim-Katav *et al*., 2016). Thanks to a radiocarbon date from core AK8 (Morhange *et al*., 2016), it is known that the Na'aman River flowed near the tell at least until around 2000 years BP (1975 ± 30 BP; 43 years cal. BC – 79 years cal. AD; Poz-53647). Another radiocarbon date from core AK2, drilled 150 meters west of core AK8, shows that the choked lagoonal estuary existed until 1035 ± 35 BP (897 – 1117 years cal. AD; Poz-50075).

<u>Unit C:</u> Coastal plain under aeolian and indirect fluvial influence

This unit is situated between 230 and 120 cm depth. It is composed of sands (75%) with a minor proportion of silts and clay (18%). The gravel fraction (7%) is composed of a majority of reworked ceramics (imported amphorae: 4-5th century BC). The ostracods are absent from the unit, except at the base. The macrofauna density is very low represented and composed of freshwater and terrestrial shells. This unit reflects the final phase of the progradation of the coastal plain after the infilling of the lagoon.

-1, closer to

Core AK-XV-2 (32°55'9.86"N; 35° 5'15.71"E) is located ca. 80 meters east of AK-XV-1, closer to the tell, 439 cm above the present mean sea level. With a length of 450 cm, it also reaches the rocky substratum composed of kurkar. We were able to discriminate the same bio-facies as in AK-XV-1 but with a different thickness (Figure 5).

Unit A: leaky lagoonal estuary until ca. 400 years cal. BC

Unit A is located between 286 cm and 450 cm depth. Two radiocarbon dates show that this unit developed before the 5th century BC (2540 ± 30 BP; 798 – 547 years cal. BC; Poz-78034). This age is confirmed by ceramics similar to those discovered in the core AK-XV-1 dated to the 5-4th century BC. However, the identification of the ceramics shows earlier sherds dated to the Iron and Middle Bronze Age (Juglets, amphoraes, cooking pots; Figure 5). The important erosion marks on the ceramics attest to the presence of the sea. As for unit A of core AK-XV-1, the texture is sandy. The gravel fraction increases and represents 36% of the total sediment in the first two thirds of the unit. They are mostly composed of small rounded pieces of ceramics (non-identifiable) and pebbles. The ostracod fauna is composed of a mixture of species with various ecological affinities, as in the core AK-XV-1. However, in this core, the lagoonal assemblage, comprising *Cyprideis torosa*, is dominant (55%). The freshwater to mesohaline species represents 23% of the total species. The coastal assemblage is the third assemblage represented (19%). The same three species prevail (*Aurila convexa*, *Loxoconcha rubrincta* and *Pontocythere elongata)*. The faunal density varies throughout the unit. The maximum density (ca. 800 valves for 20 grams of sands) occurs when the freshwater assemblage is dominant even though the mean density is lower than 100 valves for 20 grams of sediment. Macrofauna, with a low density throughout the unit, attest to freshwater and marine influences.

Unit B: choked lagoonal estuary between ca. 400 years cal. BC. and ca. 1000 years cal. AD

Unit B, located between 270 and 286 cm, is thinner than in AK-XV-1. As confirmed by the discovery of a potsherd (amphorae) dated to the 6-4th century BC, this unit was deposited during the same period as unit B of core AK-XV-1. Sediments are composed of brown silts associated with freshwater (eg. *Candona neglecta*, *Illyocypris gibba*, *Heterocypris salina*) and lagoonal (*Cyprideis torosa*) ostracods, although coastal species are present at the base of the unit (eg. *Aurila convexa*, *Loxoconcha rubrincta*).

This unit is situated between 184 and 270 cm depth. It is composed of fine aeolian sands and

Unit C: coastal plain

This unit is situated between 184 and 270 cm depth. It is composed of fine aeolian sands and fluvial-derived sediments. In this unit, the fauna is quasi-absent consistent with the final phase of the coastal progradation and the creation of a terrestrial environment.

The western facade of the tell

Core AK-XV-3 (32°55'13.77"N; 35°5'6.71"E) was drilled on the western side of the tell, 524 cm above the present mean sea level. With a length of 625 cm, it also reaches the rocky substratum composed of kurkar. The bio-sedimentology results allow us to elucidate four units (Figure 6).

Unit A: Infratidal environment in the Late Bronze/Early Iron Age

The base of the unit is dated to the Middle Bronze or Iron Age, as confirmed by the discovery of a piece of amphorae (or cooking pot). The unit is situated between 440 and 600 cm depth and is radiocarbon dated to 2830 ± 30 BP (1083 – 906 years cal. BC; Poz-78037) in the middle of this facies. Ceramics found at the top of unit A are dated to the Persian-Hellenistic period. These ceramics were transported by the sea and have been more eroded by waves than the ceramics discovered in the other cores that testify to a greater exposure to the open sea. The sedimentary texture of the unit is sandy (90%). The coarse fraction (10%) includes coarse gravels, rounded pebbles, pieces of ceramics and some broken shells. This marine sediment is mostly composed of fine sand, identical to the present-day sandy facies of Haifa Bay, south of Akko.

The ostracod fauna comprises a mixture of coastal (51%), brackish lagoonal (29%) marine lagoonal (10%), and marine (10%) species. The lagoonal species are composed of *Cyprideis torosa*, a very euryhaline species that can tolerate fresh to marine waters. Coastal and marine species are very diversified. We identified 22 coastal and marine species, dominated by *Aurila convexa*, *Aurila woodwardi*, *Loxoconcha rhomboidea*, *Loxoconcha rubrincta* and *Pontocythere elongata*. The ostracod density is low, characteristic of an open coastal environment exposed to swell and waves. Some marine species have been reworked from the upper part of the infratidal zone, such as *Bittium reticulatum*, *Donax variegatus*, *Messalia brevialis* and *Nassarius corniculus*.

Unit B: prograding sandy beach between the 7th century BC and the 13th century AD

Unit B, located between 300 and 440 cm depth is dated between the Persian-Hellenistic period, by ceramics found in the core, and the agricultural soil dated to the crusader period. The sediment texture is the same as in unit A. The gravels are less abundant and smaller than in unit A. In this unit, fauna is absent, typical of an emerged prograding beach. Furthermore, this unit is situated above present mean sea level.

Unit C: agricultural soil from the crusader period

This unit is situated between 182 and 300 cm depth. It comprises a mixture of sands, silts and clay and gravels composed of reworked ceramics of amphorae from the 6-4th century BC and other sherds from the Middle Bronze Age onwards. This unit is interpreted as an agricultural soil. In fact, during the Crusader period (ca. 13th century AD) this area was a plowed agricultural zone. It was tilled by the Pisans who settled in Saint-Jean-d'Acre (Artzy 2015). In Rey's examination of the Crusader period accounts (Rey, 1878), he found that the gardens extending from the northern banks of the Na'aman river to the southern outskirts of the tell, belonged to the Genovese who cultivated orchards there, similar to those in Damascus (Artzy, 2015).

Unit D: Aeolian sand deposition after the 13th century

The supratidal environment, situated between 120 and 182 cm depth, is composed of fine aeolian sand. This sand derives from the nearby beach. In fact, the western part of Haifa Bay is formed by an important dune field (Zviely *et al.*, 2006).

Presentation of the core undertaken in the Old City of Saint-Jean-d'Acre

Core AKKO3 (32°55'12.32"N; 35° 4'10.21"E) is located in the "Old City" of Akko, a few tens of metres from the modern artificial harbour, ca. 200 cm above the present mean sea level. With a length of 520 cm, the core is composed of marine sands and reaches the substratum of the Carmel coast clay (Figure 7).

Unit A: open pocket beach before the Hellenistic period (330 BC)

Unit A, situated between 340 and 500 cm depth reached a hard layer of cemented rocks covering the clay substratum. The gravels represent 32% of the total sediment and are composed of angular pieces of grey sedimentary rocks of various sizes and of rounded gravels. The sands represent 56% of the total sediments and the fine particles 12%. The sand texture is uniform throughout the whole unit; the sands are dominated by medium sands (43%). Ostracod faunal densities are relatively low and often lower than 10 valves for 20 grams of sands. There **are** brackish and marine lagoonal (53%), coastal (40%) and marine (7%) species. Coastal species are dominated by *Aurila convexa*, *Aurila woodwardi* and *Loxoconcha rhomboidea*. The most represented marine species are *Bairdia corpulenta* and *Quadracythere* sp. The macrofauna shows a typical infratidal faunal assemblage dominated by *Bittium reticulatum* and *Rissoa ventricosa* with subsidiary species from lagoonal environments (eg. *Cerastoderma glaucum*), upper muddy-sand assemblages (eg. *Cerithium vulgatum*) and from hard substrates (eg. *Conus mediterraneus*, *Fusinus* sp.).

Unit B: semi-protected pocket beach between 360 – 170 years cal. BC and ca. 200 – 600 years cal. AD

Unit B, situated between 238 and 340 cm depth shows the same general texture as unit A. The sand fraction is dominant (60%). The gravels and the silts fraction respectively represent 30% and 10% of the total sediment. The base of the unit (340 cm depth) is radiocarbon dated to 2170 ± 30 BP (360 – 170 cal. years BC; Poz-78041) and the top of it (248-254 cm depth) is dated to 1995 ± 30 BP (202 – 592 cal. AD; Poz-81536). Nevertheless, between 320 and 330 cm we found two reworked sherds from the same maritime transport container

(Storage jar or amphorae), dated between the Early-Byzantine and the Crusader period (ca. 500-1300 AD). The sand texture is the same as in unit A. The ostracods show a little increase in density and exceed 10 valves for 20 grams of sediments. We find the same ecological groups as in unit A, but the brackish lagoonal assemblage with *Cyprideis torosa* is dominant (57%). Marine lagoonal species (10%) occur increasingly at the top of the unit, like the coastal assemblage (29%). In contrast to the previous unit, marine species comprise just 3% of the total. Regarding the macrofauna, there are no discernable changes between the two units. The various proxies evoke a pocket beach environment, partially sheltered by the presence of the Akko promontory that protected the beach from the north-eastern waves.

<u>Unit C: infilling of the harbour after 200 – 600 cal. BC</u>

This unit is situated between 113 and 238 cm depth and is composed of coarse sediments. The gravel and the sand fraction respectively represent 41% and 43% of the total sediments. Coarse, medium and fine sands each comprise a third of the sand texture. The radiocarbon date (1995 ± 30 BP; 202 – 592 years cal. BC; Poz-81536) does not match the broken ceramics dated to the Crusader period discovered at the same depth and probably attests to reworking or dredging. Nevertheless, these sherds are incrusted with marine organisms (*Vermetus triqueter*) which demonstrate that a very shallow marine environment was still present during Muslim or Crusader periods. This unit would correspond to the infilling of this sector of the harbour which could no longer be used for the docking of boats at the time of the Crusades, as proposed by Galili & Rosen (2017). Ostracods are dominated by coastal (43%) and marine lagoonal species (40%). The lagoonal assemblage shows a drastic decrease and represents 12% of the total species. The proportion of marine species (6%) is low and essentially concentrated at the base of the unit. Furthermore, the density decreases towards the top of the unit. The macrofauna is still characteristic of infratidal sand assemblages but, at the base of the unit, we note the dominance of the hard substrate assemblage species *Mytilaster marioni*.

From a stratigraphic perspective, this core highlights a classic regressive sequence (Coe, 2003). Deposition of marine sands after sea-level stabilisation led to the progressive progradation of the coastline in a seaward direction. No classic ancient harbour parasequence *sensu* Marriner & Morhange (2006) has been identified.

DISCUSSION

Coastal changes and the palaeogeography of Tel Akko

The study of the three cores undertaken close to the tell, in association with the results of previous studies (Sivan & Inbar, 1983; Kaniewski *et al*., 2013, 2014; Morhange *et al*., 2016), allows us to probe coastal changes related to sediment input at base-level in the area of Tel Akko during the last 4000 years.

Evolution of the southern shore of the tell: from an open marine bay to an infilled lagoonal estuary

On the southern facade of the tell, Morhange *et al*. (2016) analysed three cores located more than 100 metres south of the limit of the tell. Our two cores, drilled closer to the tell, allow us to elucidate the main stages of coastal evolution of the area (Figure 8).

The first transect was undertaken south of the tell in an east-west direction. Cores AK 8 and AK 9 (Morhange *et al*., 2016) are ca. 140 m apart (Figure 9). The stratigraphy attests to marine sand with coastal, lagoonal and freshwater fauna. In AK 9, the marine sand unit is thicker and the top of this unit is situated ca. 180 cm above present m.s.l., a sign of the development of an emerged beach in this zone after 2400 ± 35 BP (745-394 years cal. BC; Poz-78033). In AK 8, the top of the unit is situated 1 m below present m.s.l. and is contemporaneous to the unit identified in AK9. This could reflect the natural slope of the beach (ca. 0.28%). This marine sand is directly followed by fine grey silts with coastal and freshwater fauna at the base, changing to freshwater fauna at the top. Nevertheless, the chrono-stratigraphy highlights important differences between the two cores. It is difficult to precisely date the open marine environment. We can merely state that it is older than ca. 2830 ± 35 BP (787-401 years cal. BC; Morhange et al., 2016).

The second transect comprises the cores AK-XV-1 and AK-XV-2, situated immediately at the foot of the tell, and core AK 8 (Morhange *et al*., 2016), around 150 metres to the south (Figure 10). This transect records the same units. At the foot of the tell, we observe a sandy beach including many rounded potsherds dating from the Middle Bronze to the 5-4th century BC and rounded pebbles corresponding to a relatively high-energy environment situated in the foreshore zone. The top of the marine-dominated unit in AK 8 is contemporaneous with the marine-dominated unit of AK-XV-1 and AK-XV-2 and highlights the natural slope of the beach situated in the southern part of the tell (ca. 0.30%). The upper unit (choked lagoonal estuary) is thicker to the south (AK 8) and is around 100 cm above present m.s.l. near the tell. The potsherds collected during the coring campaign show that the core AK-XV-2 was drilled close to the ancient entrance of the tell in contrast to AK-XV-1 which contains more harbour-like material.

Analysis of the two transects, on the southern shore of the tell, highlight two main stages in the evolution of the landscape:

(1) First, the open marine environment formed during the Holocene marine ingression is recorded at the base of AK 8 and AK 9. Analysis of another core, south of the tell, highlights the presence of an open marine environment between 4000 and 2900 cal. years BP (Kaniewski *et al*., 2014). Progressively, the westward progradation of the coastal plain and the concomitant shift in the position of the Na'aman mouth leads to the transformation of the area into a leaky lagoonal estuary during the Iron Age and the Persian period, as attested by the presence of freshwater fauna in marine sands. The course of the Na'aman was probably situated at the foot of the tell at this time. The marine sediment recorded in the cores until the 4th century BC is explained by the proximity of the inlet allowing deposition of marine sand. This facies is the same for the present mouth of the Na'aman (Avnaim-Katav *et al*., 2016). They show that the river mouth is open to the sea all year round.

(2) The closure of the lagoonal estuary and the deposition of fluvial-derived fine sediments could be explained by: (i) the avulsion of the Na'aman displacing it closer to the tell; and/or (ii) the closure of the inlet. This river-dominated environment (mesohaline lagoon) shows that the circulation of boats in this area was very limited and explains the relocation of harbour activities on the western façade of the tell, forming an open anchorage easy to access (Figure 8).

A natural open harbour on a prograding sandy beach on the western façade of Tel Akko in Late Persian/Early Hellenistic time

On the south-western part of the tell, an Israeli Archaeology Authority salvage project, revealed the presence, on the slope itself, of a small industrial area dating to ca. the 4th century BC. Late Persian to early Hellenistic remains were discovered (Artzy, 2012; Figure 11).

Cores AK 5 (Morhange *et al*., 2016) and AK-XV-3 (this study) were drilled at the foot of the hill, just a few meters west of an excavation area (Artzy, 2012; Figure 11). The cores show that, during the MBA, the sea washed the western shore of the tell (Figure 12). Sediment input into Haifa Bay mainly came from local rivers and the Nile because the bay constitutes the northernmost and final depositional sink of Nile-derived quartz sand, transported from the Nile delta by longshore currents (Zviely, Kit & Klein, 2007). Under typical weather conditions, the Carmel headland area at the southern entrance of Haifa Bay provides a natural barrier that prevents sand from entering the bay. Only rare high south-west breaking waves can produce the strong northerly longshore currents needed to overcome the headland barrier and move sand eastward into the bay. The annual net longshore sand transport into Haifa Bay was estimated by Zviely, Kit & Klein (2007) to be 80 to 90 × 10^3 m^3 from south to north. This explains that, during the Holocene, the bay trapped more than 700 million m^3 of sand. However, in the northern part of the bay, where the Na'aman mouth is located, the annual net longshore sand transport is negligible (Lichter, Zviely & Klein, 2009). Between AK 5 and AK-XV-3 the sand accumulation seems to have been relatively modest during the MBA illustrating a difference with the aggradation rates measured by Porat, Sivan & Zviely (2008) in the centre of the bay. In fact, they show that the central Zevulun plain has prograded at an average rate of 40-50 cm/year since 4000 BP. The sea was present until the Persian-Hellenistic periods as confirmed by sea-transported/eroded ceramics found in the cores. This facies corresponds to the sand facies bearing shells and ceramics discovered during the archaeological survey and delineates a high-energy coastline (Figure 11). It was at this time that the coast started to prograde westwards, probably associated with increasing sediment inputs from the Na'aman River.

Semi-open pocket beach in the Old City

Archaeological excavations show that the most recent finds at Tel Akko date to the 3rd century BC. After this time, the tell was abandoned in favour of the Old City of Saint-Jean-d'Acre (Artzy, 2015). While previous scholars attributed the construction of the artificial harbour to the Persians, in order to accommodate Gambyse's fleet on its way to Egypt (Linder & Raban, 1965; Raban, 1983, 1993), Ptolemy 2 (285–246 BC) seems to have responsible for the massive constructions in the "Old City" and of the harbour (Artzy, 2015). The harbour in ancient times was composed of two basins (Figure 13). Galili *et al*. (2010) analysed the ceramic content of the sediments dredged in the artificial harbour, mainly in the western basin, and showed that the remains (potsherd, anchors…) are significant for the Hellenistic, Roman and Byzantine periods while very few archaeological artefacts are earlier. Nonetheless, because dredging did not reach the substratum, they cannot exclude that the oldest remains have not been dredged. Discoveries show that the harbour had important trade activities because of the high quantity of imported amphorae and domestic vessels found in the harbour's sediments. These remains point to extensive trade relations with Mediterranean countries and to large-scale imports from the Aegean (Galili *et al*., 2010). The presence of stamped handles dated to the 2nd century BC may be related to military activity in the harbour, linked to the Ptolemaic and the Seleucid armies. For Galili *et al*. (2010), the abundant Hellenistic artefacts were embedded in fine silt sediment, which is characteristic of low-energy waves and good mooring conditions in the western basin. This basin was at least 3m deep, thus enabling the anchoring of medium-size and even large vessels (Galili & Rosen, 2017).

Our coring shows that the Old City has been in part built on a palaeo-marine pocket beach much like other harbour cities of the Levant such as Tyre and Sidon (Marriner &

Morhange, 2005). In fact, our work shows that the area situated east of the Khan-al-Oumdan (Core AKKO3) was washed by the sea during the Hellenistic period (2170 ± 30 BP; 360-170 cal. years BC; Poz-78041; at 135 cm b.s.l.). Even if the ostracod fauna seems to show a sheltered environment due to an increase in the proportion of lagoonal taxa (from 15 to 57% of the total ostracod assemblage), the sediment texture is coarse, composed of sands and pebbles. This coarse facies contrasts with the fine-grained sediments usually found in protected harbours (Marriner & Morhange, 2006). A recent study suggests that the southern mole was built during the Hellenistic/ Early Roman Period (Silberstein, Galili, & Sharvit, 2017). We propose that the coarse sediments recorded in our core are not linked to the absence of efficient harbour works but that grain size could be explained by the location of the core (Figure 13). In effect, the core was drilled on the margin of the harbour basin and this unit reflects the sediments of the mid-tidal zone, reworked by the sea in contrast to the bottom of the harbour basin, much better protected (Galili *et al.*, 2010). The effective protection of the harbour that began in Hellenistic times and was reinforced during Roman times is not clear in our core. The Roman period is characterised by a revolution in harbour design linked to the widespread development of hydraulic concrete that enabled the construction of large offshore structures (Brandon *et al.*, 2014). The necessity for a well-protected harbour is important, because Akko harbour was the main Roman sea gate to the land of Israel until the construction of *Caesarea*'s harbour by Herod at the end of the 1st century BC. Because of the supremacy of the other harbours of Palestine (e.g. *Caesarea Maritima*) the harbour of the Old City of Akko rapidly became less attractive and important. The top of the core represents the harbour abandonment phase. Sediments are coarser, ostracods are very scarce and the water column of the harbour does not allow the circulation of any boats. Modern dredging of the western basin reveals very few artefacts dating to the Early Islamic, Crusader and Ottoman periods.

This suggests that the western basin was partially silted at that time because of poor maintenance (Galili *et al*., 2010). The large deep-sea boats were moored in the eastern basin, probably along wooden piers.

CONCLUSION

Our new cores highlight important landscape changes along the coastal zone of Tel Akko during the last 4000 years. This important trade city from the early 2nd millennium BC onwards, had two MBA maritime façades: one to the south and one to the west. The southern façade probably constitutes a better-protected environment linked to the presence of the Na'aman mouth even if the western façade was probably used to pull boats onto the beach. Since the Persian period, the southern lagoonal estuary started to be infilled. On the western façade, the presence of buildings linked to harbour activities dated to the Persian period shows that the anchorage situated in the west probably became the main open natural anchorage. From Bronze Age to early Hellenistic times, the harbours of Tel Akko can be defined as open harbours, much like Byblos in Lebanon (Stefaniuk *et al*., 2005; Carayon, Marriner & Morhange, 2012). During Hellenistic times, the tell was abandoned in favour of the lower city of Saint-Jean d'Acre. A core drilled on the promontory shows that since this period, the coastline has prograded several meters in the area of the modern harbour of Akko.

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